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CANADIAN PATENT

METHOD AND APPARATUS FOR INCREASING THE HEAT
TRANSFER FROM SOLIDS TO LIQUID HELIUM

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No. OF CLAIMS 15

1 This invention relates in general to a method and apparatus for increasing the rate of heat transfer between a heated surface and a liquid coolant and finds particular utility in the cooling of superconductor elements and circuits. Additionally, the invention relates to a housing or support for said superconductor elements and circuits having surfaces which are particularly adapted to increase the rate of heat transfer between said surfaces and said liquid coolant in contact therewith.

 It is desirable to transfer heat from the surface of a heated material to the liquid coolant at a rate sufficiently high to limit the unavoidable increase in the temperature of the material. One obvious way of
10 accomplishing this is to increase the area of the surface in contact with the coolant. In many instances however, such as where size is an important factor, as for example in the miniaturization of electrical components and circuits, this approach is inherently unfeasible. This is especially true in the field of cryogenics. Here, the temperature of superconductor elements or circuits must be precisely controlled at extremely low temperatures. Temperature variations in the order of 10^{-3} degrees Kelvin can have significant and often adverse effects upon the operation of cryogenic devices. Generally, the coolant employed is liquefied
20 helium maintained at a temperature below 4.2 degrees Kelvin and under its saturated vapor pressure. The element or circuit may be housed in a liquid tight compartment under a vacuum, or containing helium gas, for example, with the compartment being immersed in the liquid helium, alternatively, the circuit may be fabricated on the surface of a substrate of a good thermally conductive material with the circuit including the substrate being immersed in the liquid coolant. The problem of heat transfer under such conditions is complicated as the liquid coolant is normally boiling: this is an unusual condition with respect to the average heat



1 transfer system. This invention, however, finds particular utility in
2 just such an environment, that is, an environment in which the heat gen-
3 erated by the superconductor element or circuit including the same and
4 absorbed by the housing or substrate is dissipated so as to prevent a
5 temperature buildup which would otherwise occur. By virtue of this in-
6 vention, more efficient cooling at very reduced temperatures is obtained.

7 Broadly speaking, the object of this invention is to provide a
8 method for the more efficient cooling of any heat transferring surface by
9 a liquid coolant such as helium.

10 Another object of this invention is to provide a unique housing or
support for electrical components and circuits, such as superconductors
and their circuits, whereby the heat transfer efficiency in a liquid cool-
ant system is enhanced.

These and other objects are achieved in accordance with the pre-
sent invention by treating the surface or surfaces in contact with the liquid
coolant and from which heat is to be transferred to provide surface imper-
fections therein adapted to promote the formation of bubbles, said bubbles
upon disengagement from said imperfections rising in said liquid coolant
to carry heat away from said surface and promote movement of said liquid
20 coolant over said surface.

A more specific object relative to the superconductor housing or
support is achieved by providing such a housing or support for immersion
in a liquified gas coolant such as helium, the surface area of said housing
or support being provided with surface imperfections to promote bubble
formations thereat when so immersed.

These and other objects of this invention will become more appar-
ent from a detailed description of the accompanying drawings.

In the drawings:

1 Figure 1 is a diagrammatic illustration of a heat generating element, for example a cryotron, mounted on a substrate with the assembly immersed in a liquid bath; and

 Figure 2 is a cross section of the heated substrate of Figure 1, partly in section, showing imperfections in the surface of said substrate and the formations of bubbles thereat.

 Referring to Figure 1, a bath 10 may contain a liquid coolant 11. The heat transfer body 12 may be a substrate upon which a cryotron 13 is mounted, the cryotron being insulated by insulation 15. The substrate
10 should be a good thermal conductor such as aluminum, silver, or the like. The heat generated during operation of the cryotron 13 is transferred by conduction into the body 12 and from the surface thereof into the liquid coolant 11. In a specific embodiment, this liquid may be liquefied helium gas at 4.0 degrees Kelvin and under its saturated vapor pressure. Conventional associated equipment may be employed in a system of this type for maintaining the proper temperature and pressure of the helium, none of this equipment being of particular pertinence to the invention.

 While Figure 1 illustrates the cryotron 13 being isolated from the
20 liquid helium 11 by a protective layer of insulation 15, it is contemplated that the insulation may be omitted if desired, conditions permitting, so that both the substrate 12 and the cryotron 13 are completely enveloped by the liquid helium. An additional variation contemplated is that of placing the cryotron and substrate in a housing or box as indicated by the broken line 16, and immersing said housing in the liquid helium.

 Referring jointly to Figures 1 and 2, and more particularly to Figure 2 the section of the substrate 12 is shown as being provided with a plurality of imperfections 14. This showing of the substrate will

1 suffice for any heat transferring surface. These imperfections, for example, may be point imperfections such as conical or hemispherical indentations, or they may take the form of lines cut into the surface of the substrate material. They should have dimensions corresponding to those of the bubbles to be formed, for example, 0.1 millimeter. It has been found that the provision of these imperfections on the surface to be cooled promotes the formation of bubbles at the points of imperfections. The progressive development of a bubble is shown in connection with the central, conical imperfection of Figure 2 where it will be seen that the original formation takes place at the apex of the conical imperfection and that as the bubble grows in size it expands out of the imperfection and finally breaks free from the surface of the substrate 12 to rise to the top of the liquid coolant. During the formation of these bubbles which are due to the vaporization of the coolant, heat equal to the latent heat of vaporization of the coolant is withdrawn from the surface. The bubbles soon become large enough to disengage from the surface and rise to the top of the liquid. In so rising, they promote the circulation of the coolant over the surface to be cooled. This process, therefore, may be identified as pool boiling.

20 It has been found that by intentionally providing the surface with these imperfections the rate of heat transfer from the heated surface to the coolant can be increased. By providing more imperfections more bubbles are formed and more heat is transferred from the surface to the liquid. Of course, the most efficient transfer of heat occurs when as many gas bubbles as possible are formed. This can be accomplished by providing a maximum number of imperfections in the surface to be cooled. A maximum is reached of course when the spacing of these imperfections approximate the size of the bubbles.

Experimental evidence has shown that the inclusion of at least two imperfections in a surface area of 11.4 square centimeters increased the heat transfer from 25 milliwatts per degree Kelvin per square centimeter for a smooth surface to 350 milliwatts per degree Kelvin per square centimeter for a surface containing said imperfections.

The imperfections in the surface of the material may be made therein by treating the surface with some tool or even originally molding these imperfections into the surface.

What has been described is one embodiment of the present invention. Other embodiments obvious from the teachings herein to those skilled in the art are contemplated to be within the spirit and scope of the following claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method of increasing the rate of heat transfer from a heated surface that comprises:

- a) treating said surface to provide therein at least one imperfection adapted to promote bubble formations thereat;
- b) determining the size of said imperfection so as to substantially correspond to the dimensions of the bubbles formed, and
- c) immersing said surface in a liquid coolant, whereby said bubbles upon reaching sufficient size for disengagement from said imperfection rise in said liquid to thereby carry heat away from said surface and to promote movement of said liquid over said surface.

2. A method of increasing the rate of heat transfer from a heated surface as defined in claim 1 wherein said imperfection is in the form of a line cut into said surface.

3. A method of increasing the rate of heat transfer from a heated surface as defined in claim 1 wherein said imperfection is in the form of a point imperfection.

4. A method of increasing the rate of heat transfer from the non-supporting surface of a substrate that comprises:

- a) treating said surface to provide therein at least one imperfection adapted to promote bubble formations thereat, and
- b) immersing said surface in liquid helium, whereby said bubbles upon reaching sufficient size for disengagement from said imperfections rise in said liquid helium to thereby carry heat away from said surface and to promote movement of said liquid helium over said surface.

5. A method of increasing the rate of heat transfer from the non-supporting surface of a substrate as defined in claim 4 wherein said im-

perfection is in the form of a line cut into said surface.

6. A method of increasing the rate of heat transfer from the non-supporting surface of a substrate as defined in claim 4 wherein said imperfection is in the form of a point imperfection.

7. A method of increasing the rate of heat transfer from the non-supporting surface of a substrate as defined in claim 4 wherein the size of said imperfection substantially corresponds to the dimensions of the bubbles formed.

8. In combination, a substrate, a superconducting element formed on said substrate, and a liquid coolant in contact with selected portions of said substrate surface, said selected portions of said substrate having at least one imperfection.

9. A combination as defined in claim 8 wherein said imperfection is in the form of a line cut into said substrate surface.

10. A combination as defined in claim 8 wherein said imperfection is in the form of a point imperfection.

11. A combination as defined in claim 8 wherein the size of said imperfection substantially corresponds to the dimensions of the bubbles formed.

12. In combination, a substrate, a superconducting element formed on said substrate, a housing for containing said substrate and superconducting element, and a liquid coolant in contact with the outside surfaces of said housing, said housing having imperfections formed on the outside surfaces thereof and adapted to promote bubble formations.

13. A combination as defined in claim 12 wherein said imperfections are in the form of lines cut into the outside surface of said housing.

14. A combination as defined in claim 12 wherein said imperfections are in the form of point imperfections.

15. A combination as defined in claim 12 wherein the size of said

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imperfections substantially correspond to the dimensions of the bubbles
formed.

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